

CHARACTERISTICS OF ATMOSPHERIC ORGANIC AND ELEMENTAL
CARBON PARTICLE CONCENTRATIONS IN LOS ANGELES

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ABSTRACT

A fine particle air monitoring network was operated in the Los Angeles area during 1982. It was found that carbonaceous aerosols accounted for typically 40% of total fine particle mass loadings at most monitoring sites. The ratio of total carbon (TC) to elemental carbon (EC) in ambient samples and in primary source emissions was examined as an indicator of the extent of secondary organic aerosol formation. It was found that TC to EC ratios at all sites on average are no higher than recent estimates of the TC to EC ratio in primary source emissions. There is little evidence of the sustained summer peak in the ratio of TC to EC that one might expect if greatly enhanced secondary organics production occurs during the photochemical smog season. The TC to EC ratio does rise by the time that air masses reach the prevailing downwind edge of the air basin as would be expected if secondary organics are being formed during air parcel transport, but the extent of that increase is modest. These results suggest that primary particulate carbon emissions were the principal contributor to long-term average fine aerosol carbon concentrations in the Los Angeles area during 1982.

1. INTRODUCTION

Fine carbonaceous particulate matter is emitted from most combustion processes.¹⁻⁴ These primary carbon particles consist of organic compounds accompanied by black non-volatile soot components that have a chemical structure similar to impure graphite.⁵ The black portion of these particulate emissions, commonly referred to as elemental carbon, is a major contributor to visibility reduction in urban areas,⁶⁻¹¹ and some investigators recently have suggested that light absorption by elemental carbon plays an important role in the earth's radiation budget.¹²⁻¹⁶ Organic aerosol components present in vehicular emissions¹⁷ and in ambient samples¹⁸ have been found to be mutagenic in the Ames test, and soots have been shown to be carcinogenic in experimental animal studies.¹⁹ As a result, there is considerable interest in the behavior of primary carbon particle concentrations in the atmosphere, and in how those concentrations might be controlled.

Primary emissions of carbonaceous aerosols are not regulated separately from the remainder of the urban aerosol complex. Routine monitoring programs in the United States do not provide data on aerosol carbon concentrations in the atmosphere, and data on the emissions of carbonaceous aerosols are sparse. As a result, information sufficient to support engineering studies of methods for controlling fine carbon particle concentrations is lacking. This control strategy development problem is further complicated by the fact that several studies suggest that a large fraction of the organic

aerosol is secondary in origin (i.e. formed in the atmosphere from the low vapor pressure products of reactions involving gaseous hydrocarbon precursors).²⁰⁻²⁴ If the overwhelming majority of aerosol carbon was formed in the atmosphere as a secondary product of photochemical reactions, then controls on direct emissions of carbon particles from sources might have little effect on urban air quality.

The present paper is the first of a series designed to describe methods for achieving deliberate control of urban fine carbon particle concentrations. In this work, the approach used to acquire an air quality model verification data set for organic and elemental carbon concentrations will be described. This method will be demonstrated in Los Angeles, and key characteristics of Los Angeles carbonaceous aerosol air quality will be defined. The spatial and temporal distribution of aerosol carbon concentrations over an entire annual cycle will be described. The geographic areas that experience the highest aerosol carbon concentrations will be identified and related to source density and pollutant transport patterns. The ratio of total carbon to elemental carbon in the atmosphere will be examined as an indicator of the extent of secondary organic carbon aerosol formation. In subsequent papers, air quality models will be tested against this data set. The importance of major source types to observed aerosol carbon air quality will be quantified through that modeling effort. Mathematical programming methods for defining the most attractive approaches to aerosol carbon control then will be illustrated, using the results of the air quality modeling study.

2. EXPERIMENTAL DESIGN

Throughout the year 1982, a fine particle air monitoring network was operated in the Los Angeles area at the locations shown in Figure 1. The ten stations marked with solid circles in Figure 1 are located in the South Coast Air Basin within the ring of mountains that surrounds Los Angeles. Samples also were collected from March through December at a remote off-shore site, San Nicolas Island, in order to define pollutant concentrations in the marine environment upwind of Los Angeles. Twenty-four hour average fine particle filter samples were taken simultaneously throughout the network every sixth day during 1982 on a schedule coordinated with the National Air Surveillance Network (NASN) high volume sampling schedule.

The ambient sampling equipment constructed for use in this study is illustrated in Figure 2, and was designed to obtain a near mass balance on the chemically identifiable portion of the atmospheric fine particle loading. Ambient air at a flow rate of 25.9 m^3/min was drawn through an AIHL cyclone designed to remove particles with aerodynamic diameter larger than $2.1 \mu\text{m}$.²⁵ The air flow containing the fine particle fraction then was divided between four parallel filter assemblies. Each filter substrate was chosen for compatibility with a particular chemical or physical analysis procedure.

Samples taken for organic and elemental carbon determination were collected on 47 mm diameter quartz fiber filters (Pallflex Tissuquartz 2500 QAO) that had been heat treated to 600°C in air for more than 2 hours to lower their carbon blank. Filter samples were collected at a

flow rate of 10 μ m, and all filters were refrigerated between collection and analysis to minimize losses due to volatilization and evaporation.

Organic and elemental carbon concentrations on these filters were measured by the method of Huntzicker et al.²⁶ and Johnson et al.²⁷ Four quartz fiber filter disks (0.25 cm² each) cut from a 47 mm filter are inserted into the combustion zone of a temperature programmed oven. Volatilization of organic carbon occurs in two steps: at 400°C in flowing Helium and at 600°C in He. The volatilized carbon is oxidized to CO₂ over a MnO₂ catalyst at 1000°C, reduced to CH₄, and measured by a flame ionization detector. Elemental carbon is measured by combusting the residual carbon on the filter disks to CO₂ in a O₂ (2%)-He (98%) mixture at 400°C, 500°C and at 750°C, followed by methanation and detection as described above. A calibration is performed at the end of each analysis by injecting a known amount of CH₄ into the oven and measuring the response. The reflectance of the filter sample is monitored continuously by a He-Ne laser during the volatilization and combustion process to detect any pyrolytic conversion of organic carbon to elemental carbon. Correction for pyrolytic conversion of organic carbon to elemental carbon is accomplished by measuring the amount of elemental carbon combustion required to return the filter reflectance to the value that it had prior to pyrolysis.

Replicate analysis of 53 filters taken from the present field experiment was used to determine the precision of the carbon analysis

procedure. Analysis of variance showed the following analytical precisions (± 1 standard deviation): organic carbon (OC), $\pm 0.54 \mu\text{g m}^{-3}$; elemental carbon (EC), $\pm 0.31 \mu\text{g m}^{-3}$; total carbon (TC), $\pm 0.64 \mu\text{g m}^{-3}$. The analytical precision of a single determination of the ratio of various carbon species concentrations was found to be (± 1 standard deviation): OC/TC, ± 0.025 ; OC/EC, ± 0.20 ; TC/EC, ± 0.20 . The analytical accuracy of each single total carbon determination during this experimental program is estimated to be $\pm 9.8\%$, and includes the effects of uncertainties in carbon analyzer sample loop volume, calibration gas, area of the punches cut from each filter, temperature and pressure variations during analysis, filter surface area and air volume sampled. The accuracy of total carbon measurements made by depositing known amounts of sucrose on filter disks and then analyzing the disks also was assessed. The average ratio of measured carbon to expected carbon was 1.01 ± 0.04 (95% confidence interval).

The filter intended for elemental and organic carbon aerosol collection was followed by a quartz fiber backup filter. This backup filter was included to permit assessment of the amount of organic carbon that can become attached to a clean filter due to adsorption of gas phase hydrocarbons or due to revaporization of organic material originally collected by the upstream aerosol filter. The extent of collection of aerosol and gas phase organics by aerosol sampling systems is dependent on the sample flow rate, temperature, and collection media used.²⁸⁻³¹ Recent atmospheric sampling experiments

conducted in Warren, MI, using dual filter units with quartz fiber filters showed that adsorption of organic compounds on backup filters as a result of sampling artifacts plus any contamination during handling accounted for at least 15% of the organic carbon collected on the upstream aerosol filter.²⁹ Analysis of three months of backup filters from the present set of Los Angeles area experiments showed that the backup filters adsorbed organic carbon during sampling and handling equal to $17 \pm 11\%$ of the organic carbon found on the preceding aerosol filters, a value similar to results obtained during the Warren, MI, experiments.²⁹

The second filter holder line shown in Figure 2 contained a 47 mm Teflon membrane filter (Membrana 0.5 μm pore size) operated at a flow rate of 4.9 ℓ/pm . Fine particulate matter collected on this filter was analyzed for the concentration of 34 trace elements by X-ray fluorescence. The Teflon filters were equilibrated at low relative humidity before and after sampling, then weighed repeatedly to obtain fine particle mass concentrations.

Samples collected on Nuclepore filters (47 mm diameter, 0.4 μm pore size) were intended for aerosol light absorption coefficient determination by the integrating plate technique.³² As a result, those filters must be lightly loaded, and a 1 ℓ/pm flow rate was chosen. A portion of each of these filters was analyzed for sulfates and nitrates by ion chromatography,³³ and for ammonium ion content by the phenolphthorite method.³⁴

The remaining quartz fiber filter shown in Figure 2 was intended

for determination of the detailed organic species present by gas chromatography/mass spectrometry. These filters were heat treated prior to use in the same manner as the other quartz fiber filters previously described in order to reduce their carbon blank. Results of the analysis of these filters will be reported elsewhere.

3. FINE PARTICLE CONCENTRATION AND COMPOSITION

Fine particle mass concentration during the year 1982 averaged between $23 \mu\text{g m}^{-3}$ and $42 \mu\text{g m}^{-3}$ within the metropolitan Los Angeles area, falling to $7 \mu\text{g m}^{-3}$ at San Nicolas Island (see Figure 3a). Most of the fine particle air monitoring sites were co-located with a National Air Surveillance Network (NASN) or South Coast Air Quality Management District high volume sampler that operated on the same 6-day schedule, and thus the average total suspended particulate matter concentration at these sites is known. As a consistency check on the fine particle monitoring data, the fraction of the total aerosol mass found in particle sizes below $2.1 \mu\text{m}$ diameter was computed, and found to constitute between 31% and 39% of the total particulate mass at the various monitoring sites. This result is in good agreement with South Coast Air Quality Management District special studies that show that 31% of TSP mass at El Monte in the Los Angeles area is present in particle sizes below $2.5 \mu\text{m}$ diameter.³⁵

A mass balance was constructed at each air monitoring site by summing the chemically identified portions of the fine particulate matter samples. Trace metals were converted to their oxides, and organic carbon concentrations were converted to an estimate of organic

species concentration. In order to compute organic aerosol mass concentration from organic carbon data alone, an estimate must be made of the mass fraction attributed to elements other than carbon (e.g., O and H) within the organic aerosol fraction. This question has been addressed by a large number of investigators in the past based on molecular scale examination of the organic material or on the basis of the ratio of extractable organics mass to carbon content. Values of the organic mass to organic carbon ratio used in material balance studies range from 1.2 to 1.4.^{10,20,36-40} (It is necessary to rearrange data in some of the above studies to place the results on a common basis.) In the present study, material balance results will be stated at both extremes of that reported range, with the organics to OC ratio set at 1.2 and at 1.4. Table 1 summarizes these results, and shows that the material balance closed to within $\pm 11\%$ of gravimetrically determined fine particle mass at all but one of the on-land monitoring stations. Individual chemical species concentrations thus are consistent with a mass balance on the fine aerosol, and the major contributors to the fine aerosol loading have been identified.

Aerosol carbon species ($EC + 1.2 \text{ to } 1.4 \times OC$) account for approximately 40% of the fine mass loading at most monitoring sites, as shown in Figure 4. At downtown Los Angeles, for example, the aerosol consists of 26.7% to 31.2% organics, 14.9% elemental carbon, 9.4% nitrate ion, 22.2% sulfate ion, 9.4% ammonium ion, 10.3% trace metal compounds, and 7.2% to 2.7% unidentified material (probably sea salt

plus water retained on the filter despite desiccation). Despite the fact that Los Angeles is located near the ocean, chloride does not appear as a major component of the fine aerosol. This is probably due to a combination of factors: (1) removal of coarse particle sea salt by the cyclone separator employed to exclude particles with $d_p > 2.1 \mu\text{m}$ and (2) halide displacement from the aerosol, for example, by reaction with nitric acid. Results at the remaining stations are very similar except for Rubidoux and San Nicolas Island. The Rubidoux samples appear much lower in relative carbon content only because total fine particle mass concentration is higher there. This is due to addition of much more aerosol nitrate at Rubidoux than is found elsewhere, plus an added contribution from soil-like minerals when compared with other sites. The unusually high aerosol nitrate levels at Rubidoux are documented by other studies that attribute those high nitrate levels to Rubidoux's location that is both far enough downwind of the Los Angeles urban area to experience high nitric acid levels and directly downwind of a large, sharply defined source of fresh NH_3 emissions from agricultural activities^{41,42} (see the NH_3 emission pattern in Figure 6 of reference 43). Soil dust levels at Rubidoux are probably governed by local soil surface conditions (dry, vacant land) in the immediate vicinity of that particular monitoring site. The aerosol at San Nicolas Island is quite different from that found over the on-land portion of the air basin, being very low in elemental carbon content.

4. CHARACTERISTICS OF ELEMENTAL AND ORGANIC CARBON CONCENTRATIONS

Fine total carbon concentrations are highest in areas of the basin with heavy traffic, such as downtown Los Angeles and Burbank (see Figure 3b). Total fine carbon concentrations at those two sites averaged 12.2 and $13.7 \mu\text{g m}^{-3}$, respectively, during 1982. Aerosol carbon concentrations decline with distance inland (the prevailing downwind direction), falling to $8.2 \mu\text{g m}^{-3}$ for air masses passing Rubidoux in the Riverside area. A similar pattern is observed for both organic carbon (Figure 3c) and elemental carbon concentrations (Figure 3d). Note in Figure 3d that the elemental carbon concentration in marine air at San Nicolas Island is very low, about $0.3 \mu\text{g m}^{-3}$ on the average. A statistical description of the aerosol carbon data set is provided in Table 2.

Aerosol carbon data at individual monitoring sites can be viewed on a seasonal basis. Figure 5a shows the time series of individual 24-hr average organic carbon samples at Lennox, a near-coastal site adjacent to a busy freeway. In Figure 5b, the time series of organic carbon concentrations has been smoothed by computing monthly average values. It is seen that the highest organic carbon values are observed in winter months, falling to a minimum in the summer. The same behavior is observed for elemental carbon at that site, as seen in Figures 5c and 5d. This pattern with high winter values and low summer concentrations is typical of primary automotive pollutants like CO and lead at that location.⁴⁴

Moving in the prevailing downwind direction from Lennox toward

Los Angeles, a similar pattern of high winter values and a summer minimum in aerosol carbon levels is observed in 1982 (Figure 6a). At Pasadena, a June minimum in fine carbon concentrations still is observed on average (Figure 6b), but individual days during the late summer show total fine carbon concentrations that are as high as the winter values. Proceeding further downwind to Upland (Figure 6c) and Rubidoux (Figure 6d), the pronounced summer minimum in fine aerosol carbon levels is absent; there even may be a relative peak in aerosol carbon concentrations in the summer at Upland.

5. COMPARISON TO EMISSION DATA

An inventory of organic and elemental carbon particle emissions to the Los Angeles area atmosphere was developed for the year 1980 by Cass et al.⁴ Aerosol carbon emissions in particle sizes less than 10 μm were estimated to total about 46 tons per day. One quarter of that total came from gasoline powered vehicle exhaust, one fourth from diesel engine exhaust, and the remainder from a large variety of stationary fuel burning, industrial and fugitive sources. In contrast, the black elemental carbon particle emissions were dominated by diesel exhaust aerosol. The ratio of total carbon to elemental carbon in primary aerosol emissions was estimated to be about 3.2:1 averaged over all sources in the area in 1980. A weighted average highway traffic emission profile of gasoline fueled vehicle exhaust, diesel exhaust, tire dust and brake dust likewise indicated a total carbon to elemental carbon ratio of about 3.2:1. These total carbon to elemental carbon ratios obtained from the 1980 emissions survey may

be slightly higher than would be obtained from a 1982 emission inventory for Los Angeles. One reason for this is that the relatively high organic carbon emissions from old non-catalyst automobiles are declining over time as catalyst-equipped new cars take their place in the vehicle fleet.

The ratio of total carbon to elemental carbon in source emissions when compared to the same ratio in atmospheric samples should be useful in detecting the presence of any large enrichment in organic aerosol in the atmosphere due to secondary aerosol formation. Fine elemental carbon aerosol is formed during combustion processes. This atmospheric elemental carbon is non-volatile, inert, and is not formed in the atmosphere by reactions involving gaseous hydrocarbon precursors. Therefore, the entire concentration of elemental carbon observed in the atmosphere is from primary emission sources. Organic carbon may be emitted as primary aerosol directly from sources, but secondary organics also can be formed in the atmosphere from the low vapor pressure products of atmospheric chemical reactions.²³ If a large fraction of the atmospheric fine carbon particle burden in the Los Angeles area is contributed by secondary organics, three features might be expected. First, the ratio of total carbon to elemental carbon in atmospheric aerosol samples should exceed that found in primary source emissions. Second, a higher ratio of total carbon to elemental carbon might be expected during the summer peak photochemical smog season. Third, the ratio of total carbon to elemental carbon might be expected to increase as one moves inland

along the prevailing downwind transport direction, in a manner similar to other secondary photochemical pollutants, like ozone.

The atmospheric fine carbon particle data were examined to note whether or not these likely indicators of high secondary aerosol levels were present during the year 1982. The discussion will begin at the upwind edge of the air basin near Lennox. Fine elemental and organic carbon concentrations at Lennox are shown in Figure 5ac. Elemental and organic aerosol concentrations are highly correlated ($r^2 = 0.98$). The daily ratio of total carbon (TC) to elemental carbon (EC) at Lennox is shown in Figure 7a. These values are fairly consistent from day to day, and are contained entirely within the range 4.0:1 to 1.8:1. In Figure 7b, the daily values of the TC to EC ratio are averaged over each month of the year 1982. It is seen that there is very little seasonal variation, with an annual average value of the daily TC to EC ratio of 2.4:1. An alternative statistic, the ratio of annual average TC to annual average EC, can be computed from Figures 3bd, with similar results. When compared to 1980 estimates of the TC to EC ratio in primary source emissions, the Lennox aerosol is not highly enriched in organic carbon relative to elemental carbon. This suggests that the carbonaceous aerosol at Lennox is dominated by primary source emissions on the average over long periods of time. This is not surprising since the Lennox site is located only about 100 m from a very large freeway, and shows the highest annual mean lead levels in the Los Angeles area⁴⁵ (again an indicator of direct vehicle exhaust influence).

The situation at downtown Los Angeles is quite similar to that at Lennox (Figure 7cd). Peak TC to EC ratios of 4:1, little seasonal dependence, and an annual average value of the daily TC to EC ratio of 2.6:1, only slightly higher than at Lennox. Moving further inland to Pasadena, the annual average value of the daily TC to EC ratio rises to 2.8:1, again with little seasonal dependence. Air parcels reaching Upland on occasion are highly enriched in organics, with daily average TC to EC ratios often above 3:1, and on occasion approaching 6:1 (Figure 7ef). This may indicate periodic intrusion of heavy loadings of secondary organic aerosol at Upland. Nevertheless, Upland shows an annual average value of the daily TC to EC ratio of 2.8:1, not greatly different from Downtown Los Angeles. Aerosol behavior further downwind at Rubidoux near Riverside is similar to that at Upland (Figure 7gh). Occasional days with high TC to EC ratios are observed, but the monthly average value of the daily TC to EC ratio shows relatively little seasonal dependence. The annual average value of the daily TC to EC ratio at Rubidoux is 2.9:1, still not greatly different from the 1980 estimates of the TC to EC ratio in primary source emissions.

Daily values of the total carbon to elemental carbon ratios at each monitoring site have been averaged over the year 1982, and are shown in Figure 8. The lowest average TC to EC ratio is at Lennox adjacent to the San Diego Freeway on the upwind edge of the air basin, while the highest on-land values are at inland sites usually associated with heavy photochemical smog, like Azusa and Rubidoux.⁴⁵

The TC to EC ratio of approximately 7:1 achieved at San Nicolas Island is due to the virtual absence of elemental carbon rather than to an anomalously high organic carbon loading.

6. SUMMARY AND DISCUSSION

An air quality monitoring protocol employing several parallel filter samples has been described that is capable of nearly closing a material balance on the chemical species contributing to atmospheric fine particle concentrations at all onland sites other than Rubidoux. Application of this approach to the Los Angeles basin during 1982 shows that carbonaceous aerosols are the most abundant fine particle species present, accounting for roughly 40% of the average fine particle ($d_p < 2.1 \mu\text{m}$) loading at most air monitoring sites.

Fine organic and elemental carbon concentrations in the western Los Angeles basin peak in winter months, like CO and Pb concentrations at those sites. Less seasonal dependence is seen in the eastern basin near Upland and Rubidoux. When averaged over an annual cycle, fine organic and elemental carbon particle concentrations are highest in heavy traffic areas like Los Angeles, Lennox and Burbank, and decline in downwind areas (Azusa, Upland and Rubidoux). This spatial distribution and seasonal dependence is consistent with that expected of primary aerosol emissions from ground level sources in Los Angeles.

The comparison of the ratio of fine total carbon to fine elemental carbon in primary emissions vs. ambient samples was explored as an indicator of the magnitude of secondary organic aerosol. Three characteristics might be expected if a large amount of secondary

organics were present: (1) a ratio of TC to EC exceeding that in primary source emissions, (2) a summer seasonal peak in the ratio of TC to EC reflecting enhanced secondary organics production during the summer photochemical smog season, and (3) an increase in the ratio of TC to EC in the prevailing inland transport direction.

Results of the 1982 field experiment show little seasonal dependence in the ratio of TC to EC. This is true at all monitoring sites on the average over periods of many months, although individual days at inland monitoring sites do show large levels of organic carbon enrichment. Either secondary organic aerosol formation in summer months is a reasonably small fraction of long-term average total carbon concentrations, or alternatively secondary organic aerosol as a fraction of total aerosol carbon is roughly the same in both summer and winter months. The annual average of the daily ratio of fine total carbon to fine elemental carbon averaged from 2.4:1 to 3.0:1 throughout the Los Angeles area during 1982, vs. about 3.2:1 in 1980 estimates of local primary source emissions. Again, little evidence of a large enrichment in organic aerosol due to secondary aerosol formation is seen on the average during 1982.

The best case that can be made for aerosol organic carbon enrichment of air parcels during transport in the prevailing inland wind direction is based on examination of differences in TC/EC and OC/EC ratios between stations. In the extreme, the annual average of the daily ratio of TC to EC rises from 2.43:1 at Lennox to 2.97:1 at Azusa and 2.92:1 at Rubidoux. These differences between Lennox and

either Azusa or Rubidoux are statistically significant with greater than 95% confidence as can be seen by computing the standard error of the TC/EC sample mean from the TC/EC population standard deviation given in Table 2. This enrichment of up to 0.54 parts organic carbon added to the 2.43:1 ratio observed at Lennox represents a +22% increase in total carbon relative to elemental carbon from one end of the air basin to the other. A +16% enrichment in total carbon relative to elemental carbon would be found between Lennox and Azusa if the analysis is based on differences in the ratio of the annual mean TC and EC values (see Figure 3) rather than on differences in the mean of the daily TC/EC ratios. The organic carbon enrichment can be isolated from total carbon by examining the ratio of OC to EC. The OC enrichment relative to EC between Lennox and Azusa is + 38% based on the mean of the daily ratio of OC to EC, but only +27% if based on the ratio of the annual mean OC to EC values (see Figure 3). One reason for the difference in these statistics is that the OC enrichment relative to EC is favored slightly during summer months when total carbon levels are lower than average. Summaries based on the average of the daily OC to EC ratio treat that ratio each day as equally important to the annual mean, while the ratio of annual means is most affected by the highest concentration events that occur in winter months. Over long averaging times, between 16% and 22% of the total carbon and between 27% and 38% of the organic carbon at a downwind location like Azusa or Rubidoux might be due to secondary aerosol formation in excess of that found at Lennox, the range depending on

the statistical measure used. By all of these measures, this enrichment contributes a minority of the total carbon and organic carbon present.

On the average over long periods of time, Los Angeles area fine aerosol carbon concentrations probably are dominated by primary source emissions. Secondary organic aerosols may be present, but they probably were not the overwhelming contributor to observed long term average fine carbon particle concentrations during 1982. This suggests that an emission control strategy that achieved a substantial reduction in primary aerosol carbon particle emissions could be expected to achieve a correspondingly large improvement in annual mean fine particle carbon concentrations in the atmosphere.

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TABLE 1

Material Balance on the Chemical Composition of
Fine Particulate Matter Concentrations - Los Angeles Area
(1982 Annual Mean)

STATION	NUMBER OF SAMPLES	PARTICULATE MASS CONCENTRATION	IDENTIFIED CHEMICAL COMPONENTS	FRACTION IDENTIFIED (%)	
		($\mu\text{g}/\text{m}^3$) (b)	($\mu\text{g}/\text{m}^3$) (d)		
Azusa	58	29.6	27.1	91.6 ^(d)	- 95.4 ^(e)
Burbank	58	28.6	30.0	105.6	- 111.3
Long Beach	58	27.5	25.9	94.2	- 98.7
Lennox	60	28.5	25.8	90.6	- 94.9
Pasadena	59	28.5	27.6	96.9	- 98.2
West Los Angeles	57	24.8	24.0	96.7	- 101.3
Los Angeles	60	32.7	30.4	92.8	- 97.3
Upland	55	27.7	25.4	91.5	- 95.4
Rubidoux	55	42.1	34.6	82.3	- 84.7
Anaheim	57	23.1	23.8	102.8	- 105.6
San Nicholas Is.	43 ^(c)	6.8	8.3	121.7	- 126.8

(a) Only those samples for which all scheduled chemical analyses are available.

(b) Determined gravimetrically

(c) March-December 1982

(d) For case of organics mass equal to $1.2 \times \text{OC}$

(e) For case of organics mass equal to $1.4 \times \text{OC}$

TABLE 2

Statistical Description of Aerosol Carbon Data

Los Angeles Area - 1982

STATION	NUMBER OF CARBON SAMPLES	<u>OC SAMPLE POPULATION</u>		<u>EC SAMPLE POPULATION</u>		<u>TC SAMPLE POPULATION</u>		<u>TC/EC POPULATION</u>	
		Standard		Standard		Standard		Standard	
		Mean ($\mu\text{g m}^{-3}$)	Deviation ($\mu\text{g m}^{-3}$)	Mean ($\mu\text{g m}^{-3}$)	Deviation ($\mu\text{g m}^{-3}$)	Mean ($\mu\text{g m}^{-3}$)	Deviation ($\mu\text{g m}^{-3}$)	Mean	Deviation
Azusa	60	5.73	2.45	3.30	1.87	9.03	4.16	2.97	0.65
Burbank	58	8.71	4.50	5.04	3.20	13.74	7.56	2.89	0.46
Long Beach	59	6.11	4.65	3.75	3.00	9.86	7.57	2.77	0.46
Lennox	61	6.18	4.39	4.51	3.16	10.69	7.48	2.43	0.37
Pasadena	60	6.79	3.38	3.95	2.07	10.73	5.35	2.79	0.36
West Los Angeles	58	5.84	3.84	3.61	2.78	9.44	6.55	2.86	0.56
Los Angeles	61	7.29	4.30	4.87	3.24	12.16	7.44	2.59	0.35
Upland	56	5.36	1.99	3.14	1.34	8.51	3.07	2.83	0.63
Rubidoux	55	5.20	2.15	3.03	1.64	8.23	3.65	2.92	0.69
Anaheim	57	5.35	2.73	3.18	2.31	8.53	4.91	2.88	0.53
San Nicolas Is.	46	1.73	0.93	0.28	0.22	2.02	1.12	*	*

* Not computed because EC concentration approached zero on a number of occasions

OC is organic carbon concentration

EC is elemental carbon concentration

TC is total carbon concentration

TC/EC is the daily ratio of total carbon concentration to elemental carbon concentration

Figure Captions

- Figure 1. Fine particle air monitoring network.
- Figure 2. Ambient sampling protocol.
- Figure 3. Fine carbonaceous particulate matter concentrations in the Los Angeles area.
- Figure 4. Material balance on the chemical composition of annual mean fine particle concentrations in the Los Angeles area - 1982.
- Figure 5. Daily and monthly average carbonaceous aerosol concentrations at Lennox, CA.
- Figure 6. Monthly average total fine particle carbon concentrations at Los Angeles, Pasadena, Upland, and Rubidoux.
- Figure 7. The ratio of total carbon to elemental carbon at Lennox, Los Angeles, Upland and Rubidoux. Data shown in the second figure of each set represent the monthly average of the daily ratio of total carbon to elemental carbon at each site.
- Figure 8. Annual average of the daily ratio of total carbon to elemental carbon in the Los Angeles area - 1982.

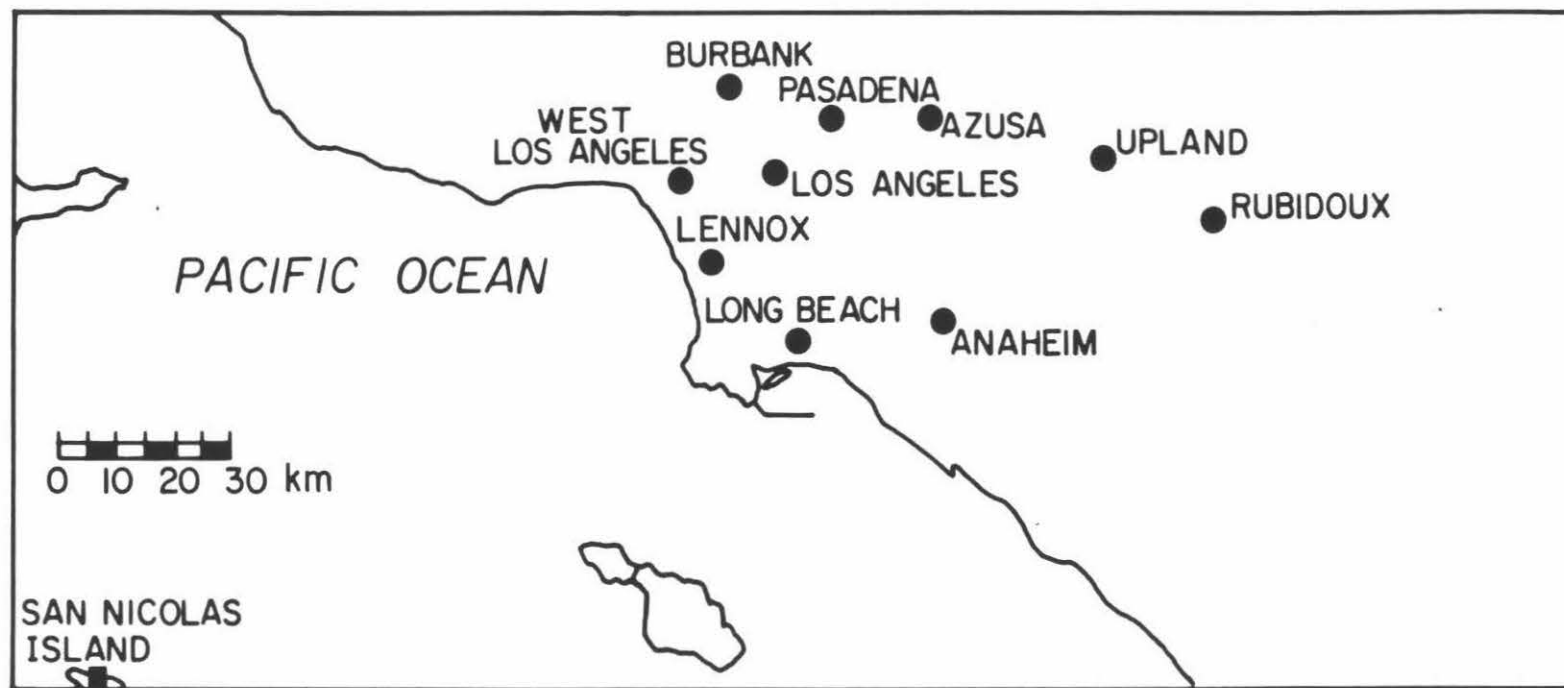


Figure 1.

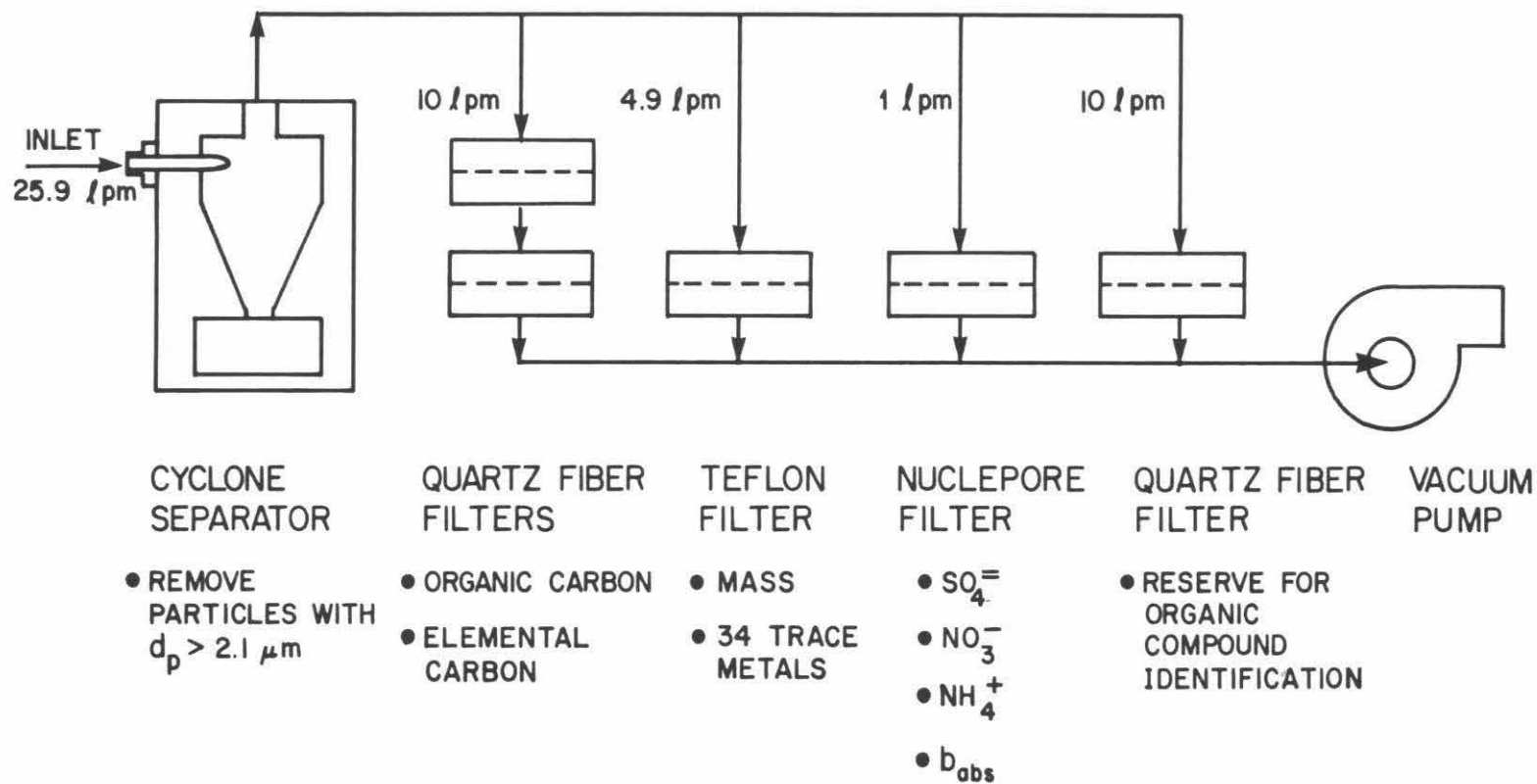
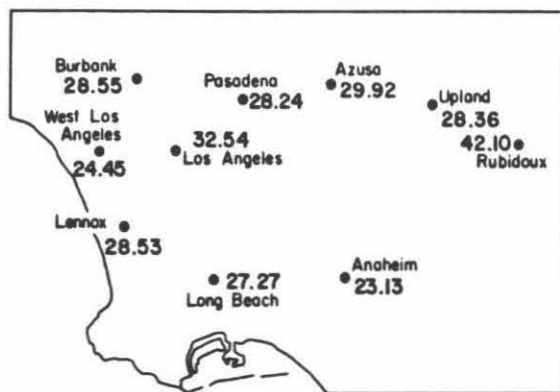


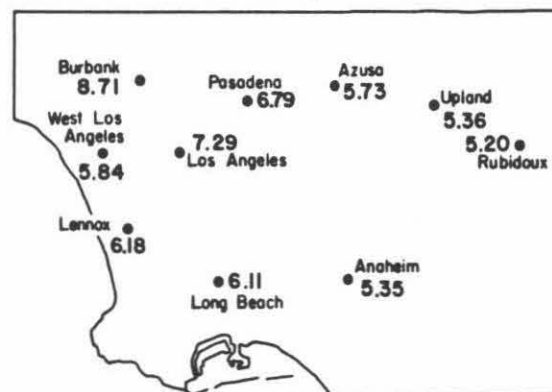
Figure 2.

FINE PARTICULATE MATTER CONCENTRATION
(1982 ANNUAL AVERAGE, $\mu\text{g}/\text{m}^3$)



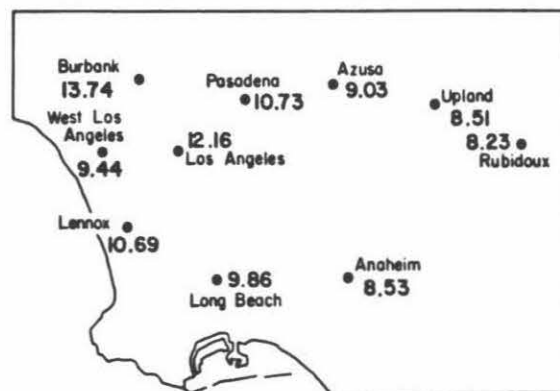
(a)

FINE ORGANIC CARBON CONCENTRATION
(1982 ANNUAL AVERAGE, $\mu\text{g}/\text{m}^3$)



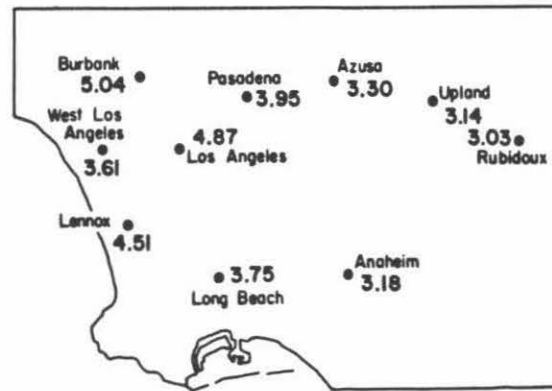
(c)

FINE TOTAL CARBON CONCENTRATION
(1982 ANNUAL AVERAGE, $\mu\text{g}/\text{m}^3$)



(b)

FINE ELEMENTAL CARBON CONCENTRATION
(1982 ANNUAL AVERAGE, $\mu\text{g}/\text{m}^3$)



(d)

Figure 3.

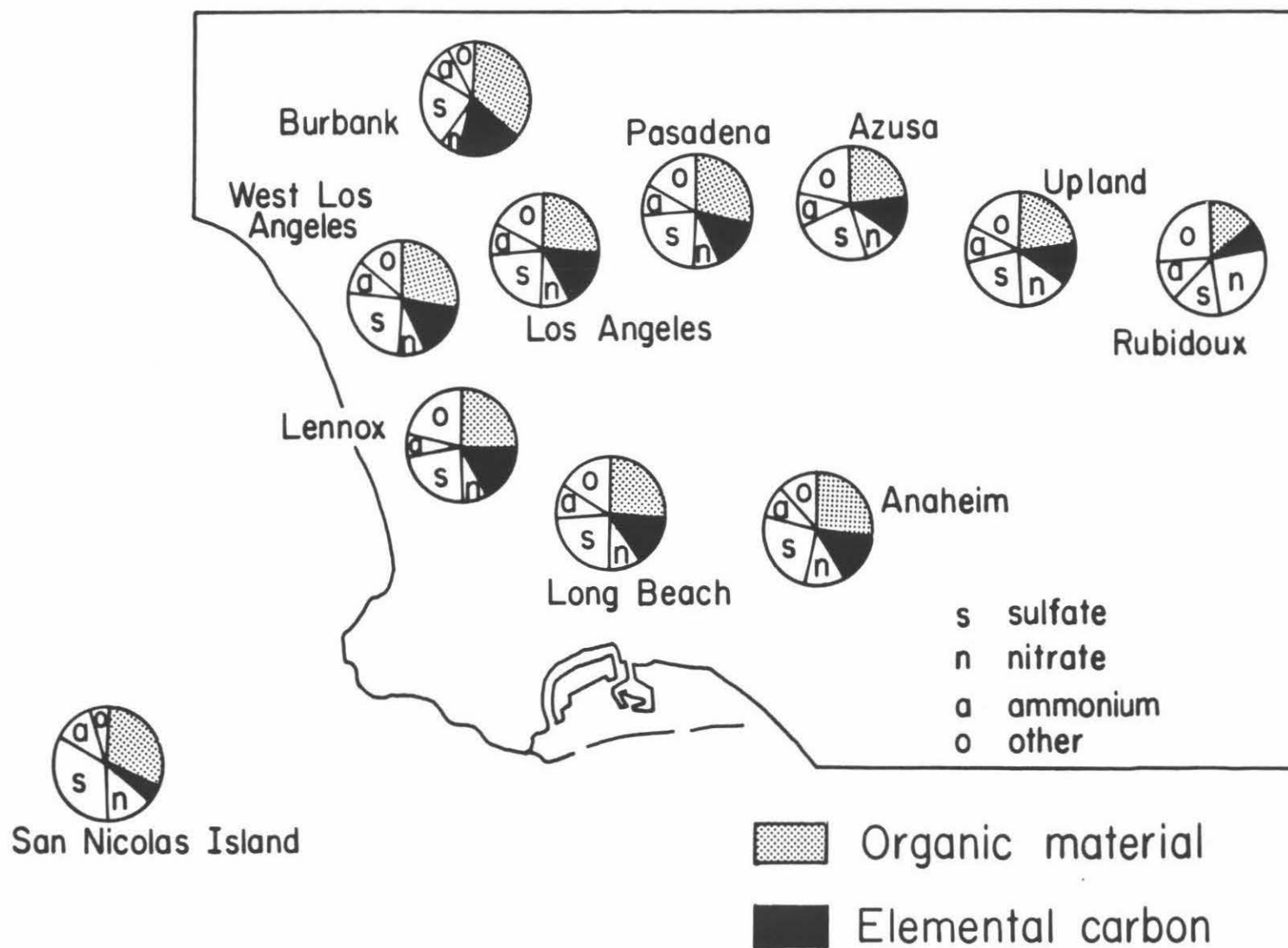


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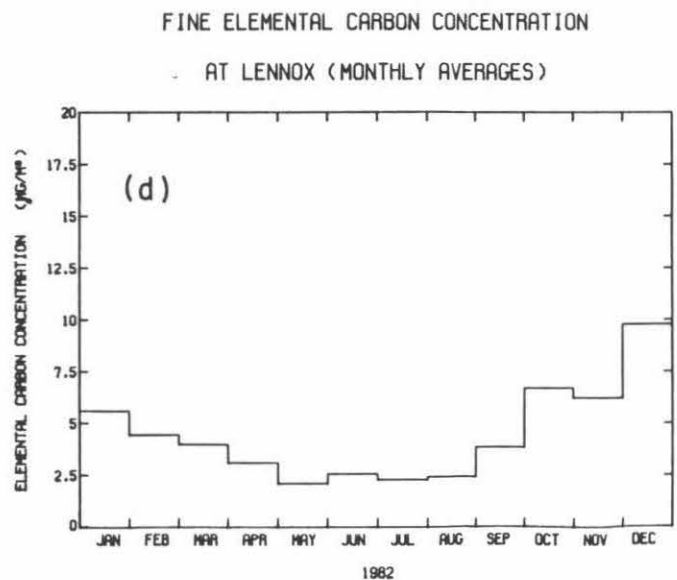
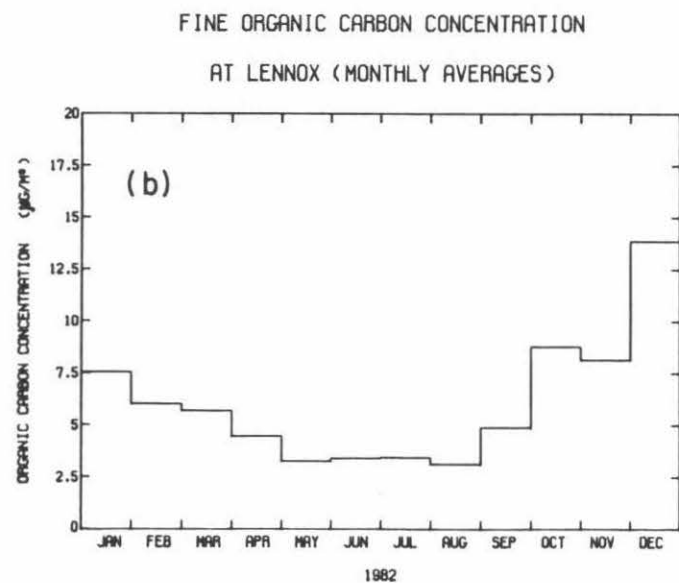
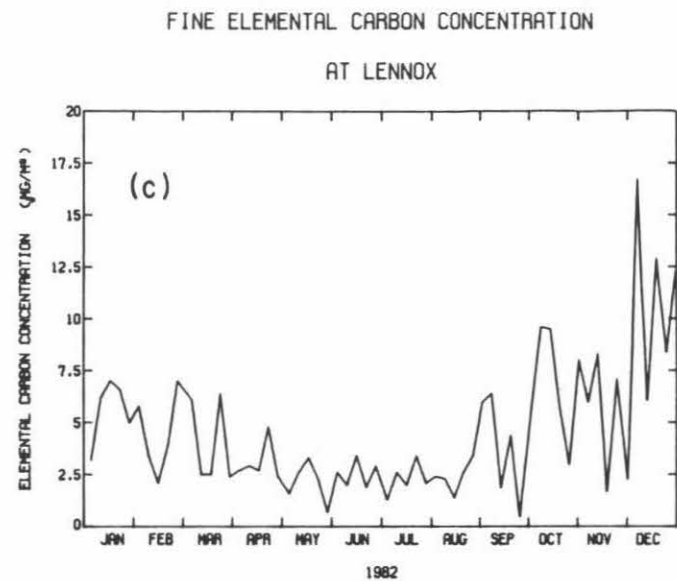
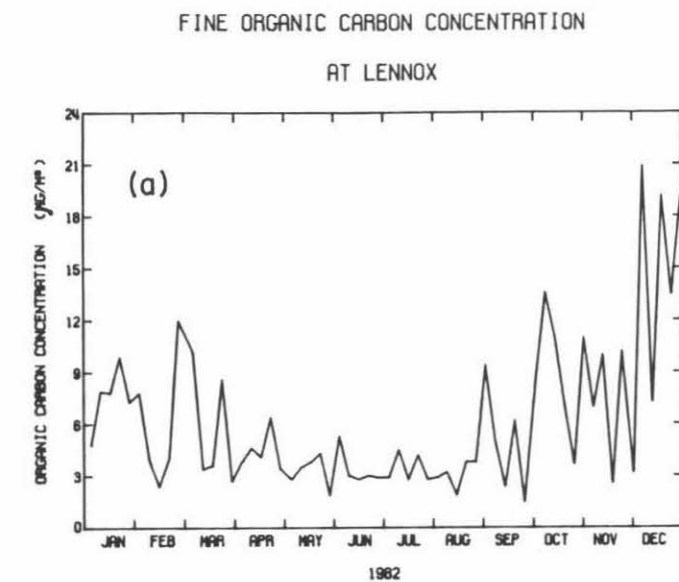


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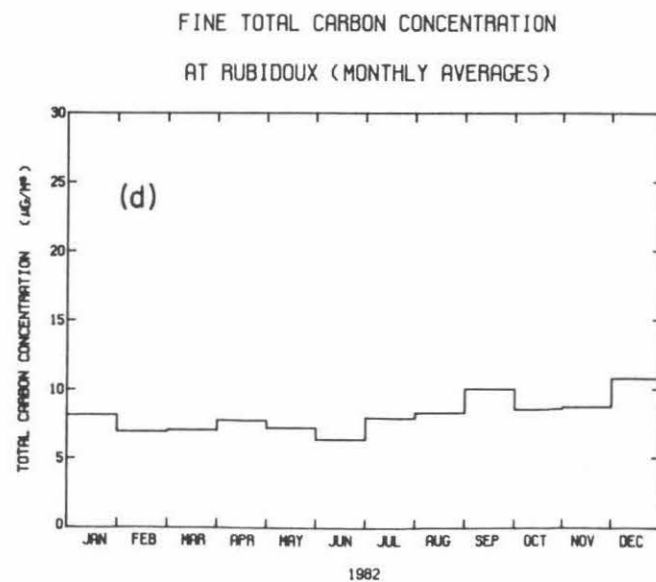
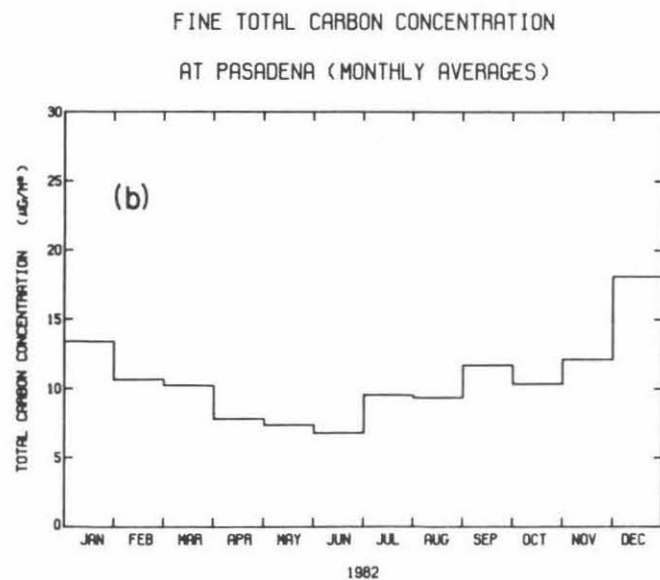
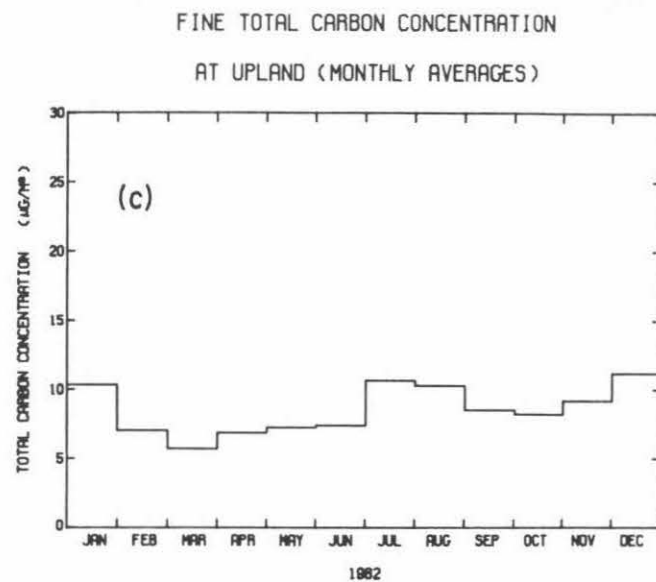
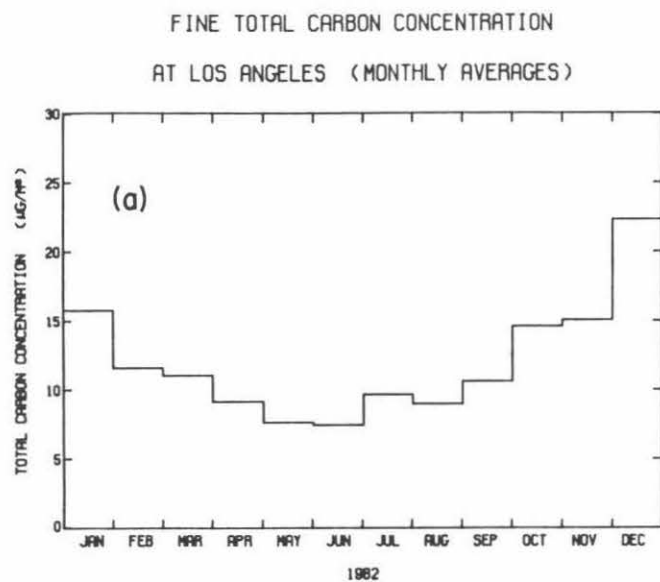


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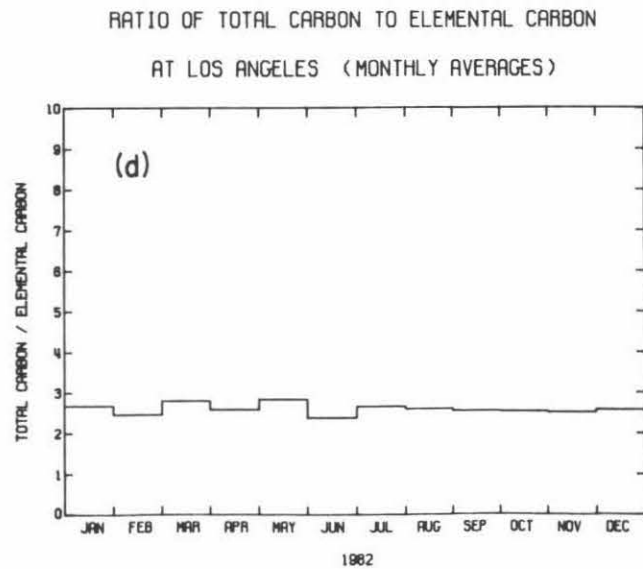
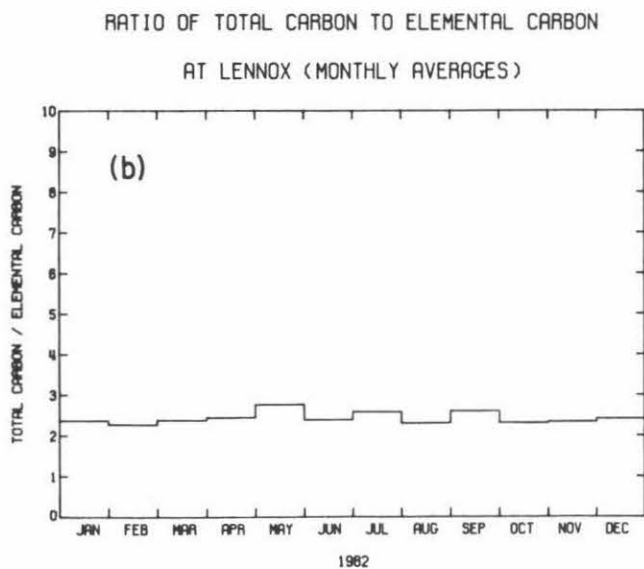
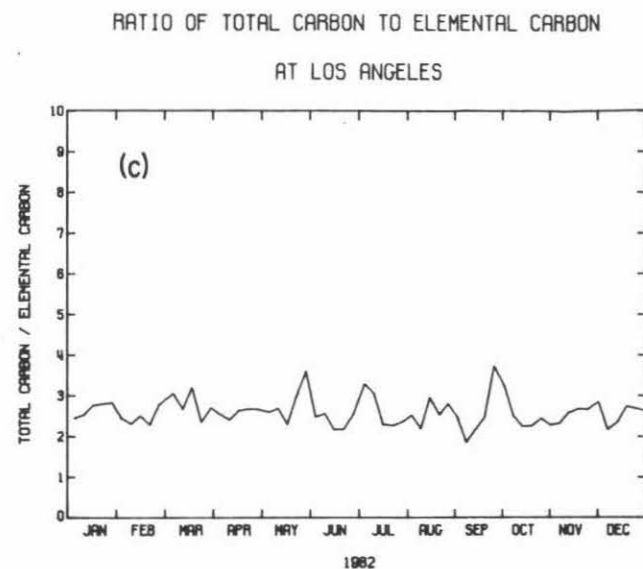
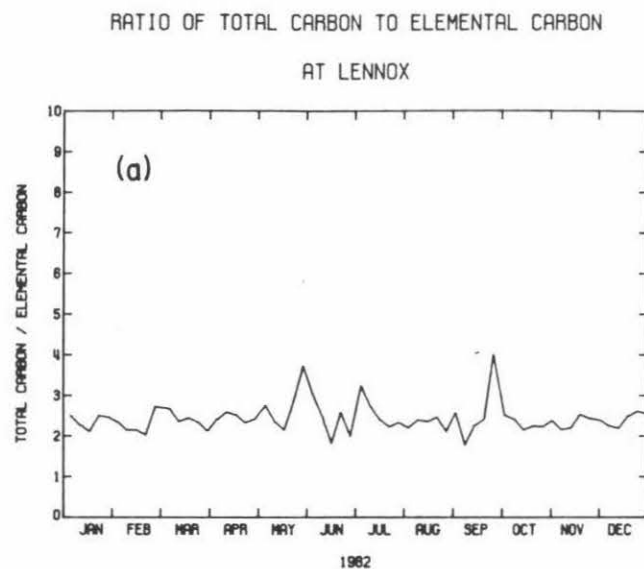
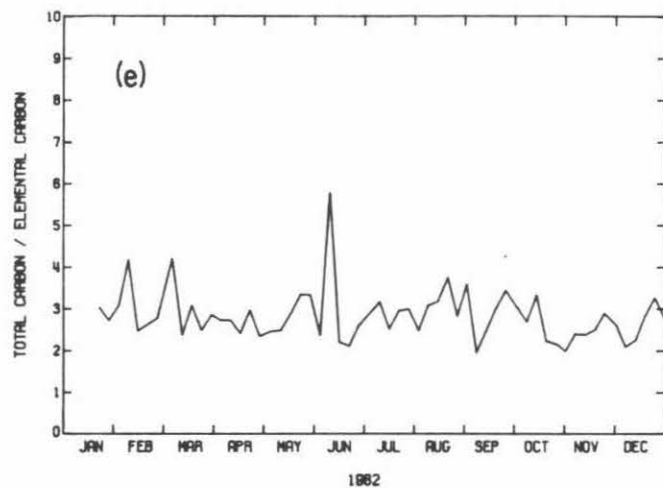


Figure 7abcd

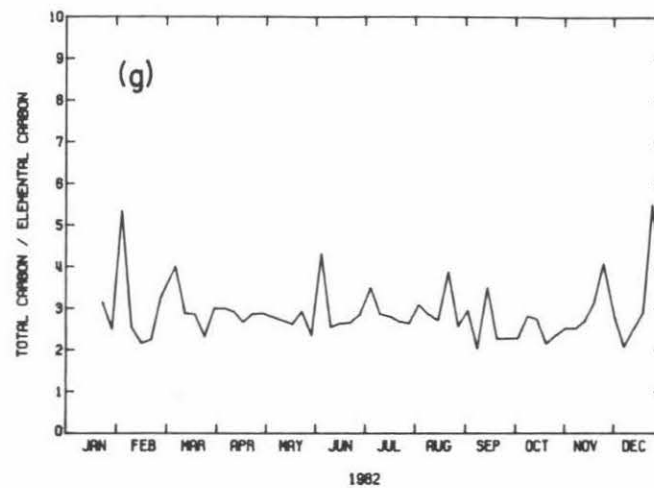
RATIO OF TOTAL CARBON TO ELEMENTAL CARBON

AT UPLAND



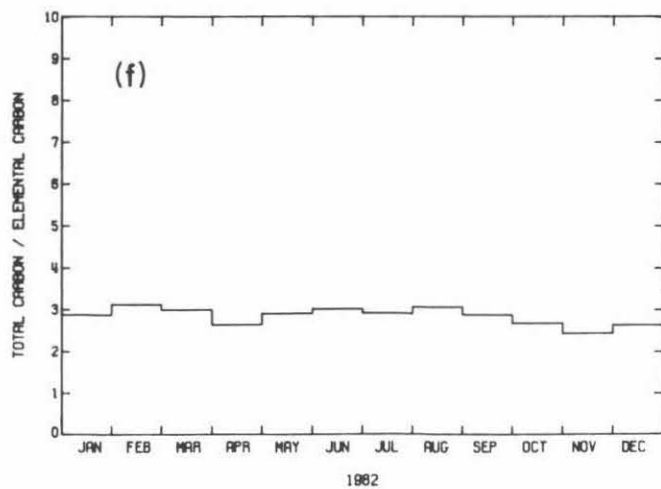
RATIO OF TOTAL CARBON TO ELEMENTAL CARBON

AT RUBIDOUX



RATIO OF TOTAL CARBON TO ELEMENTAL CARBON

AT UPLAND (MONTHLY AVERAGES)



RATIO OF TOTAL CARBON TO ELEMENTAL CARBON

AT RUBIDOUX (MONTHLY AVERAGES)

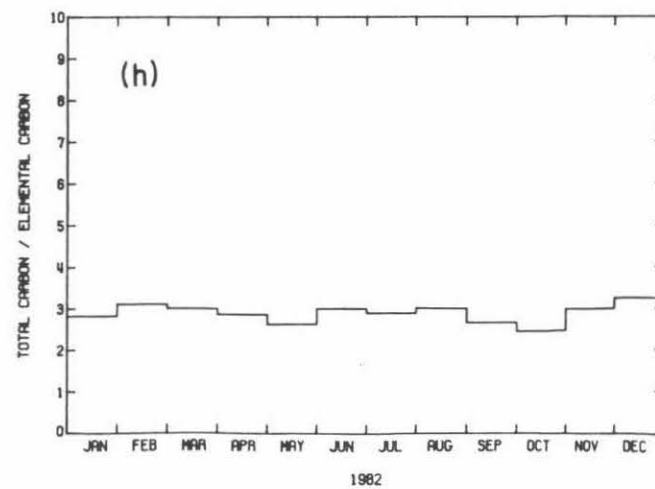
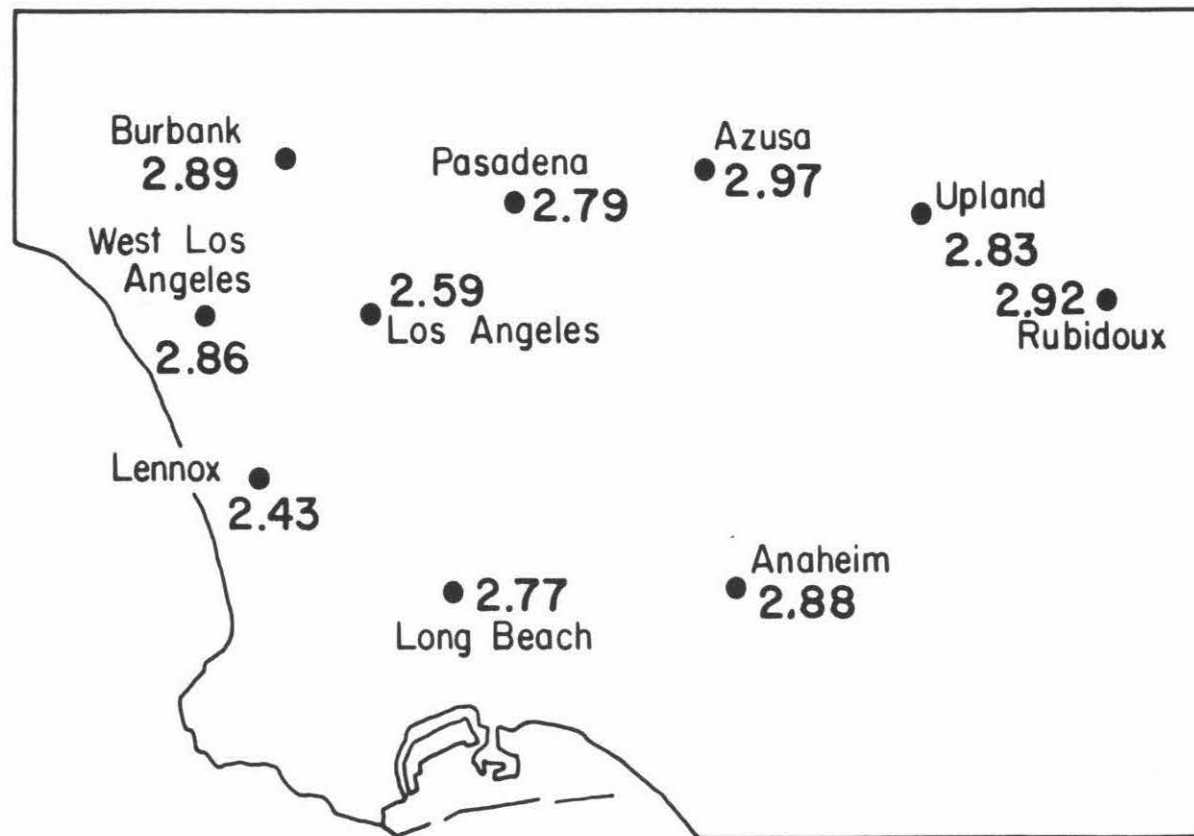


Figure 7efgh

TOTAL CARBON / ELEMENTAL CARBON (1982 MEAN)



San Nicolas Island
~7.

Figure 8